



LAT Project Office – SLAC

DCN No.
LAT-XR-00442-1**DOCUMENT CHANGE NOTICE (DCN)**

SHEET 1 OF 1

ORIGINATOR:	Warren Davis	PHONE:	650-926-4349	DATE:	11/27/01
CHANGE TITLE:	Initial Release of Calorimeter Level III Specification			ORG.:	Systems Engineering
DOCUMENT NUMBER	TITLE			NEW REV.	
LAT-SS-00018	GLAST LAT Calorimeter Subsystem Specification			9	

CHANGE DESCRIPTION (FROM/TO):

This is the initial release of the LAT-SS-00018 document (Draft D8) to configuration management. This release version includes the recommendations of the 3/28/01 peer requirements review (LAT-MR-00311).

The following changes since the peer requirements review are also included in this release:

- 1) Req. 5.2.1 - Combined old low limit and high limit energy range requirements into one single energy range requirement to remove confusion. No change to required performance.
- 2) Req. 5.3.1 - Revised the explanatory note to read: "Low energy measurements require energy loss measurement in the TKR to achieve specified resolution. This spec is for CAL+TKR measurements."
- 3) Req. 5.3.4 - Single Crystal Energy resolution changed from <1% to <2% and added comment explaining verification method.
- 4) Req. 5.5.5 - Position resolution requirement changed from <1.5 cm to <3 cm
- 5) Req. 5.5.6 - Angular resolution requirement changed from $7.5 \times (\cos(\theta))^2$ to $15 \times (\cos(\theta))^2$
- 6) Req. 5.8 - Overload recovery time reduced from 500 microsec. to 100 microsec.
- 7) Req. 5.15 - Performance life requirement added: "The CAL shall maintain the specified performance for a minimum of five years in orbit."
- 8) Req. 5.16 - Reliability requirement: Updated to 96% reliability in five years. Removed old Operability requirement.

REASON FOR CHANGE:

Initial Release

ACTION TAKEN: ☒ Change(s) included in new release ☐ DCN attached to document(s), changes to be included in next revision
☐ Other (specify):

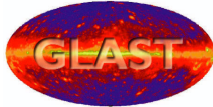
DISPOSITION OF HARDWARE (IDENTIFY SERIAL NUMBERS):☒ No hardware affected (record change only)☐ List S/Ns which comply already:☐ List S/Ns to be reworked or scrapped:☐ List S/Ns to be built with this change:☐ List S/Ns to be retested per this change:☐**DCN DISTRIBUTION:**

IDT List

SAFETY, COST, SCHEDULE, REQUIREMENTS IMPACT? ☐ YES ☒ NO

If yes, CCB approval is required. Enter change request number:

APPROVALS		DATE	OTHER APPROVALS (specify):		DATE
ORIGINATOR: (Davis)	Signature on file	11/28/01	Sys. Eng. - Elec. (Haller)	Signature on file	12/17/01
ORG. MANAGER: (Thurston)	Signature on file	11/28/01	Sys. Eng. - Mech. (Nordby)	Signature on file	11/29/01
CAL Manager (N. Johnson)	Signature on file	11/28/01			
Sys. Eng. Manager (Thurston)	Signature on file	11/28/01			
Inst. Scientist (Ritz)	Signature on file	12/13/01			
DCC RELEASE:	Signature on file	12/18/01	Doc. Control Level: <input type="checkbox"/> Subsystem <input checked="" type="checkbox"/> LAT IPO <input type="checkbox"/> GLAST Project		

 GLAST LAT SYSTEM SPECIFICATION	Document # LAT-SS-00018-09	Date Effective 28 Nov 2001
	Prepared by(s) W. Neil Johnson	Supersedes None
	Subsystem/Office Calorimeter Subsystem	
Document Title LAT CAL Subsystem Specification - Level III Specification		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter (CAL) Subsystem Specification

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes	DCN #
1		Initial Release	LAT-XR-00442

1 PURPOSE

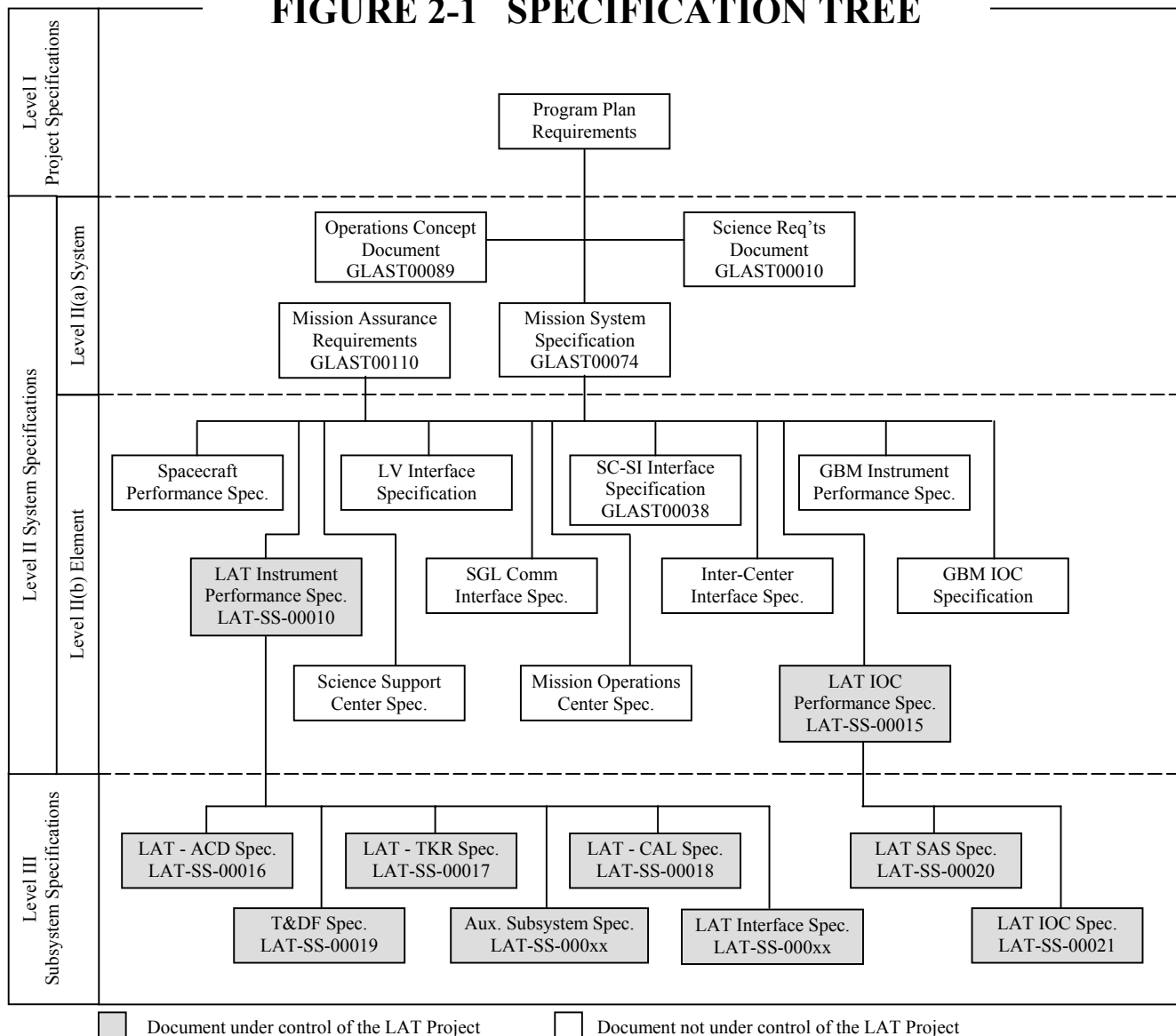
This document defines level III subsystem requirements for the GLAST Large Area Telescope (LAT) Calorimeter (CAL).

2 SCOPE

This specification captures the GLAST LAT requirements for the CAL. This encompasses the subsystem level requirements and the design requirements for the CAL. The verification methods of each requirement are identified.

This specification is identified in the specification tree of Figure 2-1.

FIGURE 2-1 SPECIFICATION TREE



Hard copies of this document are for REFERENCE ONLY and should not be considered the latest revision.

3 DEFINITIONS

3.1 Acronyms

AGN	Active Galactic Nuclei
CAL	LAT calorimeter subsystem
FOV	Field of View
FWHM	Full Width Half Maximum
GLAST	Gamma-ray Large Area Space Telescope
IRD	Interface Requirements Document
LAT	Large Area Telescope
SRD	Science Requirements Document
TBR	To Be Resolved

3.2 Definitions

γ	Gamma Ray
$\mu\text{sec}, \mu\text{s}$	Microsecond, 10^{-6} second
A_{eff}	Effective Area
Analysis	A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data.
Arcmin	An arcmin is a measure of arc length. One arcmin is 1/60 degree.
Background Rejection	The ability of the instrument to distinguish gamma rays from charged particles.
Backsplash	Secondary particles and photons originating from very high-energy gamma-ray showers in the calorimeter giving unwanted ACD signals.
Beam Test	Test conducted with high energy particle beams
cm	centimeter
Cosmic Ray	Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond.
Dead Time	Time during which the instrument does not sense or record gamma ray

events during normal operations.

Demonstration	To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
eV	Electron Volt
Field of View	Integral of effective area over solid angle divided by peak effective area.
GeV	Giga Electron Volts. 10^9 eV
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
MeV	Million Electron Volts, 10^6 eV
ph	photons
s, sec	seconds
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements
sr	steradian, A steradian is the solid (3D) angle formed when an area on the surface of a sphere is equal to the square of the radius of the sphere. There are 4 Pi steradians in a sphere.
Testing	A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation	Process used to assure the requirement set is complete and consistent, and that each requirement is achievable.
Verification	Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.

4 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the GLAST mission concept and its requirements include the following:

LAT-SS-00010, "GLAST LAT Performance Specification", August 2000

GSFC 433-SRD-0001, "GLAST Science Requirements Document"

GSFC 433-IRD-0001, "GLAST Science Instrument – Spacecraft Interface Requirements Document", Draft July 14, 2000

GSFC 433-SPEC-0001, "GLAST Mission System Specification", Draft, June 30, 2000

GSFC 433-OPS-0001, "GLAST Operations Concept"

GSFC 433-MAR-0001, "Mission Assurance Requirements (MAR) for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)"

5 REQUIREMENTS

5.1 System Description

The LAT science instrument (SI) consists of an Anticoincidence Device (ACD), a silicon-strip detector tracker (TKR), a hodoscopic CsI calorimeter (CAL), and a Trigger and Dataflow system (T&DF). The principal purpose of the SI is to measure the incidence direction, energy and time of cosmic gamma rays. The measurements are streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers.

The CAL provides the energy measurement of incident photons and background particles. These measurements, along with the information in the TKR, are used to reconstruct the energy of the incident photons. These CAL measurements are also critical to the background particle identification and rejection. The CAL responds to T&DF requests by digitizing the energy loss in the CAL and outputs the data to the dataflow system. The CAL also provides fast signals to the T&DF system that report significant energy depositions in CAL. The T&DF system analyzes these fast signals to form requests for data readout of GLAST.

The CAL subsystem consists of a 4×4 array of identical modules. Each module is a hodoscopic array of CsI scintillation crystals and associated readout electronics.

5.2 Energy Measurement Range

5.2.1 Energy Range

[Derived from LAT SS-00010 5.2.1]

The calorimeter shall support LAT calorimetry in the LAT energy range of 20 MeV to 300 GeV. The requirement for photon interaction in the LAT TKR and the ~ 1.5 radiation lengths of material in the TKR require calorimeter measurements substantially below 20 MeV.

The goal is to extend LAT calorimetry to photon energies of 1 TeV.

[COMMENT: This measurement is from the sum of all calorimeter crystals and the low energy response is critically dependant on the understanding of the energy deposition in the TKR.]

5.2.2 Single CsI Crystal Energy Measurement Range

[Derived from LAT SS-00010 5.2.1]

The energy measurement range for each of the CsI scintillation crystals shall include the range from 5 MeV to 100 GeV.

The goal is to achieve a low energy threshold of 1 MeV.

5.3 Energy Resolution

5.3.1 On-axis Energy Resolution – Low Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% (TBR) for normal incidence photons for energies in the 20 – 100 MeV range that interact in the calorimeter only. The energy resolution (1σ) shall be less than 10% for photons for energies in the 100 MeV – 10 GeV range.

Note: Low energy measurements require energy loss measurement in the TKR to achieve specified resolution. This spec is for CAL+TKR measurements.

5.3.2 On-axis Energy Resolution – High Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% for photons, with on-axis incidence, for energies in the 10 – 300 GeV range.

5.3.3 Off-axis Energy Resolution – High Energies

[SRD Table 1, #7]

The energy resolution (1σ) shall be less than 6% for photons, with angles of incidence >60 degrees off axis, for energies greater than 10 GeV. The effective area for these off-axis measurements with this energy resolution is expected to be 10 – 20% of the on-axis effective area at energies greater than 10 GeV.

The goal is less than 3%.

5.3.4 Single Crystal Energy Resolution

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be less than 2% for high energy (100 to 1000 MeV/nucleon) Carbon ions of normal incidence at a central point in the crystal with beam spot size less than 3 mm diameter.

[COMMENT: This resolution shall be tested in accelerator beams on a limited number of CDEs, which shall be read out with flight or flight-like electronics. The remaining crystals shall be qualified by similarity to the test crystals.]

5.4 On-Orbit Calibration

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall be capable of energy calibration in orbit using energy depositions from the array of cosmic ray particles. Relative light yield in each crystal shall be determined to better than 3%. Absolute light yield shall be determined to better than 10%.

The goals for relative and absolute yield are < 1% and < 3%.

5.5 Hodoscopic Configuration

5.5.1 Depth

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall have an active depth of greater than 8.4 (TBR) radiation lengths of CsI for normally incident particles.

5.5.2 Hodoscopic Layers

[Derived from LAT SS-00010 5.2.2]

The calorimeter module shall be hodoscopic.

5.5.3 Active Area

[Derived from LAT SS-00010 5.2.2]

Each calorimeter module shall provide a projected CsI area of greater than 1050 cm² (TBR) for normally incident particles.

5.5.4 Passive Material

[Derived from LAT SS-00010 5.2.2]

Passive material in a calorimeter module (everything not CsI) shall represent no more than 16% (TBR) of the total mass of the module.

5.5.5 Position Resolution

[Derived from LAT SS-00010 5.2.2, 5.2.12]

Each layer of the calorimeter shall position the centroid of a Minimum Ionizing charged particle energy deposition to less than 3.0 cm (1σ) in all three dimensions for particle incident angles of less than 45 degrees off axis.

5.5.6 Angular Resolution

[Derived from LAT SS-00010 5.2.2, 5.2.12]

The single particle angular resolution at 68% containment for the calorimeter shall be better than $15 \times \cos^2(\theta)$ degrees (TBR) for cosmic muons traversing all eight layers. (θ is the off-axis angle.)

5.6 Command and Data Interface

The calorimeter electronics shall communicate with the Trigger and Data Flow (T&DF) subsystem using LAT standard communications protocols.

5.7 Measurement Dead Time

[LAT SS-00010 5.2.13]

The dead time associated with the capture and measurement of the energy depositions shall be less than 100 μ sec. The goal is less than 20 μ sec.

5.8 Overload Recovery

[Derived from LAT SS-00010 5.2.2, 5.2.13]

The calorimeter electronics shall be capable of recovery from a x1000 overload within 100 μ sec. Recovery is defined as below the measurement readout (zero suppression) threshold.

5.9 Low Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μ s of an event) low-energy trigger signal to the LAT trigger system with a detection efficiency of greater than 90% (TBR) for 1 GeV gamma rays entering the calorimeter from the LAT field of view with a trajectory which traverses at least 6 RL of CsI.

5.10 High Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μ s of an event) high-energy trigger signal with a detection efficiency of greater than 90% for 20 GeV gamma rays entering the calorimeter from the LAT field of view that deposit at least 10 GeV in the CsI of the calorimeter.

5.11 Operating Modes

[Derived from LAT SS-00010 5.3.5]

The calorimeter shall be capable of operating continuously throughout the orbit. Operating through traversals of the South Atlantic Anomaly shall not damage the calorimeter but, because of the excessive background rates, the acquired data shall not be required to meet performance specifications.

5.12 Calorimeter Mass

[Derived from LAT SS-00010 5.3.6]

Total mass of the calorimeter shall not exceed 1492 kg. (TBR)

[COMMENT: SRR mass estimate plus 10% of ANSI/AIAA estimated reserves]

5.13 Calorimeter Power

[Derived from LAT SS-00010 5.3.10]

The power consumption of the calorimeter system, excluding conditioning, shall not exceed 91 W (TBR)

[COMMENT: Lehman review power adjusted for 80% efficiency of converters]

5.14 Environmental

The CAL shall be capable of normal operation after being subjected to the environmental conditions given in LAT-SS-00010, Section 5.3.12, Environmental.

5.15 Performance Life

[Derived from LAT SS-00010 5.3.2]

The CAL shall maintain the specified performance for a minimum of five years in orbit.

5.16 Reliability

[Derived from LAT SS-00010 5.3.2]

The reliability of the CAL shall be at least 96% in five years. Reliability is the probability that the CAL will not experience a reduction in operability below 90% due to failure of its components. Operability is the percentage of CAL channels that are operational.

6 VERIFICATION STRATEGY

The verification strategy will test, analyze (may include modeling/simulation), inspect, or demonstrate all requirements of section 5 to ensure that the instrument meets its specified requirement. The matrix below indicates the methods of verification employed to verify the science performance.

Table 6-1. Requirements Verification Matrix

Note: Verification methods are T = Test, A = Analysis, D = Demonstrate, I = Inspect

Req't #	Title	Summary	Verif. Method
5.2.1	Energy Range	20 MeV – 300 GeV	A
5.2.2	Single CsI Crystal Energy Measurement Range	5 MeV – 100 GeV	A
5.3.1	On-axis Energy Resolution – Low Energies	<50% (20 – 100 MeV) <10% (100 MeV – 10 GeV)	A
5.3.2	On-axis Energy Resolution – High Energies	<20% (10 – 300 GeV)	A
5.3.3	Off-axis Energy Resolution – High Energies	<6% (> 10 GeV)	A
5.3.4	Single Crystal Energy Resolution	< 2% for high energy carbon	T,A
5.4	On-Orbit Calibration	Relative: <3%; Absolute <10%	A
5.5.1	Depth	> 8.4 radiation lengths of CsI	I
5.5.2	Hodoscopic Layers	Hodoscopic design	I
5.5.3	Active Area	>1050 cm ² /module on axis	I
5.5.4	Passive Material	No more than 16% of total mass of CAL	I
5.5.5	Position Resolution	< 3 cm in all 3 dimensions/layer	T
5.5.6	Angular Resolution	<15 × cos ² (θ) degrees for cosmic muons	T
5.6	Command and Data Interface	LAT standard protocols	I
5.7	Measurement Dead Time	<100 μsec	T
5.8	Overload Recovery	<500 μsec	T
5.9	Low Energy Trigger Signal	CAL to provide low-energy trigger signal to the LAT trigger system	I
5.10	High Energy Trigger Signal	CAL to provide high-energy trigger signal to the LAT trigger system	I
5.11	Operating Modes	Continuous thru orbits	A
5.12	Calorimeter Mass	Not to exceed 1492 kg (TBR).	I
5.13	Calorimeter Power	Not to exceed 91 W (TBR).	T
5.14	Environmental	Must withstand environmental conditions in LAT Instrument Performance Spec.	T
5.15	Performance Life	Specified performance for a minimum of 5 years	A
5.16	Reliability	Reliability minimum of 96% in 5 years.	A